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III THE EVIDENCE OF THE FORGED PAPER

After we had to strike the word "original" from the crucial parts of the *SNML* – the printing, the drawings, the association of the binding with the disputed work – the paper remained something of a mystery. Knowing that the printing was a modern forgery, we now had to assume a variety of new possibilities concerning the origin of the paper sheets. They could be a recent production made in imitation of historic paper. It was not out of the question that a forger could have repulped historical sheets to fabricate new ones on a modern mould with old fibre material. Or, on an old mould. Another option: rather than making new paper, a historical stock could have been stolen from an archive. Ledgers or notebooks will sometimes have blank sheets. A determined thief could have hunted down blanks in an archive and secretly cut them out without being detected. It is also conceivable that a ledger had already been slimmed at an earlier time, from which point the sheets could have traveled many routes to the forgers.

In our first campaign, united by the belief that the printing was genuine, the similarity between the *SNML* watermarks and those of the regular SN stock bolstered the idea of their close connection. That "similar" is not "the same" – an essential difference that widens speculation in dating any historic paper sheet – we explained by the exceptions of proof printing. All of the other oddities separating the *SNML* stock from the regular SN paper were submitted to this argument. The proof copy paper we accepted as a lower quality variant of the regular printing paper. This proof copy being exceptional, the paper, so it was felt, could be exceptional. The only explanation of even these odd details seemed to be the extraordinary – and still true – circumstances of Galileo's working mode in the spring of 1610.

Looking at the paper again in October 2012, we searched for other clues and came to the conclusion that the *SNML* paper must be a modern forgery as well. This time, however, we had the crucial advantage of consulting a previously identified forgery in the form of the 1607 *Compasso* at the Padua Seminario Library, the existence of which we had the misfortune of being unaware until May 2012 when the *SNML* case was reopened. A single sheet of the forged 1650 *Life of Galileo* from Lima was also made available for inspection. It proved to be eye opening to compare the *SNML* stock with the paper on which the Padua *Compasso* was printed. The two papers are strikingly similar and together they differ substantially from any paper of the genuine copies and furthermore, generally do not match essential characteristics of other printing papers of the time – the Padua *Compasso* is damning company to *SNML*. Today we know that both papers, fibre to finish, are the result of similar fraudulent manipulations. Oddities of the stocks of *SNML* and the Padua *Compasso* can be pointed out in comparison to the genuine SN Graz and the Darmstadt *Com-*

passo copies, which served as our standard for the pertinent features of the regular stocks during this second examination.

A few words may be said about the methods of paper investigation utilized during the week of communal and interdisciplinary study (extended by single-day visits to the Padua *Compasso*). As soon as we confirmed the printing forgery during our October meeting, we requested permission to take fibre samples of the forged *SNML*, the Padua *Compasso*, and the Lima document, and, for comparison, the genuine papers from the Graz SN. In 2006, we had not considered fibre samples of *SNML* because the originality of the paper had not been disputed. In 2012, we again relied on the methods of visual examination employed in our first campaign, viewing the objects under different lighting conditions: normal, raking, specular raking, transmitted, ultraviolet radiation, and under magnification. Repeating the X-ray fluorescence spectroscopy of the paper did not produce any indication of trace elements that would rule out historic production.

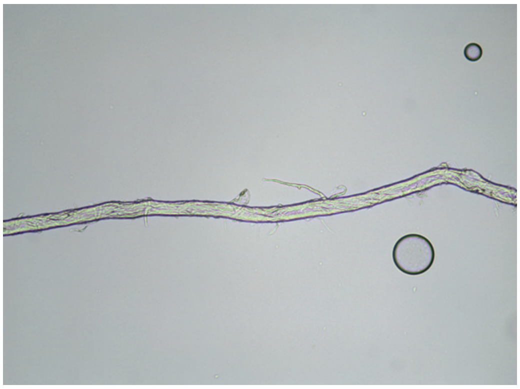
During the second campaign, a number of outside specialists were also invited to view the book, but the overall appearance of the paper was convincing enough to cause debate. We arrived at our forgery verdict for the *SNML* paper by viewing the sum of its odd features mirrored starkly in the similar, though less subtle and more numerous, oddities of the Padua *Compasso* paper. At the same time, it must be acknowledged that given the complexity of this paper forgery, not all of the observed physical phenomena can be fully explained without further inquiries. Identifying all of the material components, especially the colourants and possible surface coating in the forged paper would take further instrumental analyses, some of it associated with more extensive sample taking. The same is true for radiocarbon (carbon-14) dating of the fibres, which was eliminated after it became clear that fibre analysis was conclusive, and dating would not change the verdict. Clarifying all the processes involved in making this "aged" paper would require experimental recreations, some of which would be as complex as making the forgery itself and therefore time- and cost-intensive. The pressure to publicly release our findings to date, however, makes it pertinent to forward what insights have been gathered.

COTTON FIBRE SOURCE

The most damning evidence about the paper was the fibre identification and analysis provided by Debora Mayer in Cambridge, MA, USA.[1] All of the *SNML* stocks (Figs.1a–c) and the Padua *Compasso* stock (Figs. 1d–f) are made from cotton linters, a fibre stock highly unusual in a seventeenth-century paper. The genuine SN Graz paper is, as expected, composed entirely of bast fibres (Figs. 1g–h). Although this revelation was less a surprise after our October 2012 re-examination, it is no less significant as it practically seals the forgery verdict for the *SNML* paper. Cotton has been spun into textiles since prehistory and

1 Nine paper fibre samples were taken (max. 0,5 mm^2) by teasing fibres from chosen locations, either in the gutter or another inconspicuous location, each documented. The sites sampled are *SNML*: 2v, 16r, 19v; SN Graz: leaf 8, 19v; Padua *Compasso*: title page, verso; corner repair insert on title page; 33v; blank leaf 1. Fibres from each sample were dispersed with water on a microscope slide and examined at 100–400× magnification under a polarizing light microscope. Sample *SNML* 16r was also stained with the Graff C stain. (Results courtesy D. D. Mayer, Fibre Analysis Report, 25. 1. 2013, see also chapter V.)

Fig. 1a: Papermaking fibre sample from the forged SNML, page 2v, photographed at 100×. Cotton linter from base to tip. Fibre is about 2.25 mm long.



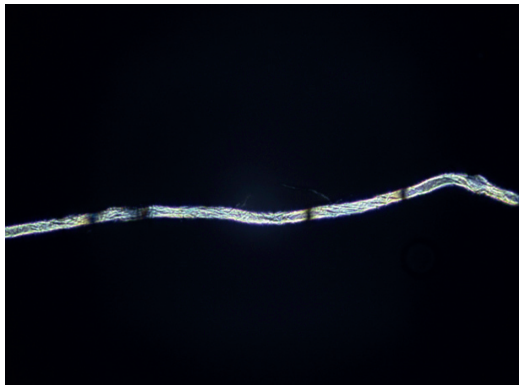
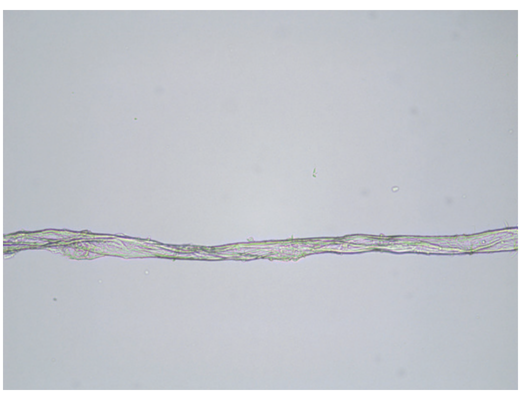


Fig. 1b: Papermaking fibre sample from the forged SNML, page 19v, photographed at 200×. Cotton linter. Only slight helical twist and striation of fibrils visible.
Fig. 1c: Same fibre as Fig. 1b viewed in cross-polarized light. Dark bands across the fibre indicate the fibril reversal region.

Fig. 1d: Papermaking fibre sample from the forged Padua Compasso, title page, photographed at 200×. Cotton linter about 1.5 mm long. Significant tapering from wide base to narrow tip.



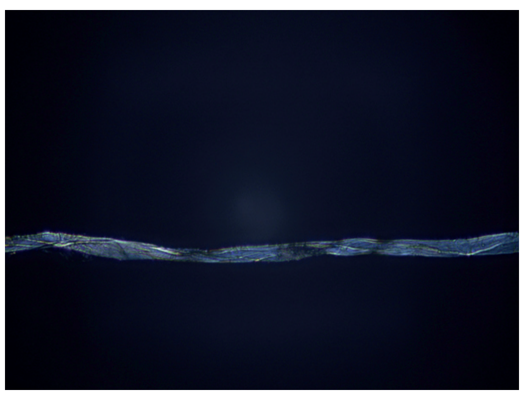


Fig. 1e: Papermaking fibre sample from the forged Padua Compasso, page 33v, magnified 200×. Cotton linter. Hint of helical twist and fibril striation.
Fig. 1f: Same fibre as in Fig. 1e viewed in cross-polarized light. Dark bands across the fibre indicate the fibril reversal region.

across continents, but the ability to separate cotton linters from the cotton seed was first developed in the nineteenth century, making it much too recent an arrival in the paper fibre market to be in genuine *Sidereus Nuncius* stocks. Cotton linters entered paper production only following the popularization of affordable cotton textiles beginning in the eighteenth century. This boosted cotton farming and in turn led to the invention of the cotton gin in 1793, which sped up the separation of the long staple fibres from the seed.[2] Cotton linters are the short remaining fuzz that, after ginning, is cut off the cottonseed with the help of the cottonseed linter machine.[3] The linter machine was first patented in the USA in the 1920s (see Appendix). Today, cotton linters are the most common fibre source in hand

g | h

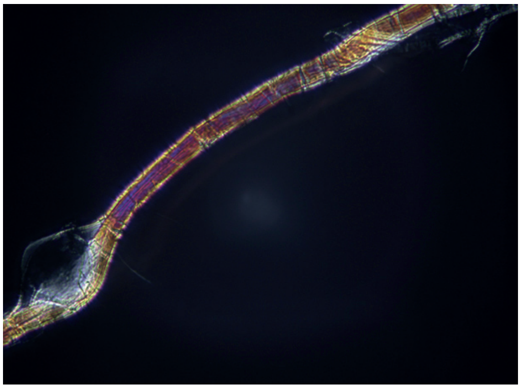


Fig. 1g: Papermaking fibre sample from the genuine SN Graz, page 19v, photographed at 200×. Beaten bast fibre. Cross marks visible across the fibre width.
Fig. 1h: Same fibre as Fig. 1g viewed in cross-polarized light. Cross marks and blue and magenta interference colours typical of bast fibres.

papermaking, easily available from craft and papermaking shops and therefore a likely supply for the forged paper. That we had decided against sampling the paper in the first investigation seems puzzling in retrospect, but was a rational choice at the time when both the paper and printing were believed to be genuine, and invasive testing was not warranted.

Given the effort in making of the forged paper, what led the forgers to use a fibre that was all but unheard of in the seventeenth century? A lack of real understanding of historical papermaking and a confusion of terminology are two probable explanations. When paper was made from the rags of discarded clothing, people wore mainly linen and woolen cloth. Because wool fibres felt when they are wet, they were not a primary source of fibres in papermaking. Linen rags were the predominant fibre source for fine "white" paper. Today, when paper is predominantly made of wood pulp, a high quality paper is made from cotton linters and often called "rag" paper. This modern understanding of the definition of rag

2 C. Wayne Smith, J. Tom Cothren, eds. *Cotton: origin, history, technology, and production*, 1999.

3 From D. D. Mayer's Fiber Analysis Report, 25. 1. 2013: „Recognizing the difference between textile grade cotton and cotton linters: The cotton linter fibre profile is distinctive – a wide base with significant tapering along the length to a pointed terminal end over a short distance. When textile grade cotton is used in papermaking it is rare to observe significant variation in width along the fibre length and to have the natural terminal ends present in a microscopic sample. In textile grade cotton, the longer staple of the cotton fibre is used, generally around 12–30 mm long and consequently requires beating and/or cutting into smaller lengths to be useful for papermaking. Due to the beating and cutting necessary with textile grade cotton for papermaking, little or no variation in fibre width is detected, natural ends are rarely present, and fibres are typically damaged from the beating process."

paper may be behind the forgers' choice of cotton. The ready availability of cotton linters for hand papermaking may have also been the deciding factor.

As the fibre source of the paper has been shown to be cotton linters, definitively modern, it is left to discuss the features of this paper that were considered to be odd, but convincingly authentic in our first analysis. These elements include the paper stocks recreated for this forgery, the structure and formation of the sheets, the unusual lack of sizing, the artificially applied surface soiling and other false signs of age and use.

Compatible with the genuine bast fibre paper of the Graz copy, the few blank sheets in the Padua *Compasso* forgery (part of the gutted eighteenth-century binding – see chapter V) are also composed of heavily beaten bast fibres. This fibre source is consistent with papermaking practice in the seventeenth through eighteenth centuries.

PAPER STOCKS AND TWIN MOULDS

Professional hand papermaking requires expert skills, even though a reasonable sheet can be made after a short introduction to the process. We can safely say that the forger did quite well in this respect. To make a sheet that looks old requires more specialized knowledge, and here the forger became creative. He closely matched the laid and chain pattern of the mould surface with respective watermarks. But to fully imitate a stock as it would be found in a historic book requires more knowledge than single sheet forgery, and this is where the forger made mistakes.

Historic handmade paper was usually made from twin moulds, i.e. two moulds with the same watermark, used in alternation by the vatman. The two moulds make twin variants of the same paper. The twins are differentiated by whether the main watermark is centered on the left side (mL) or the right side (mR) of the paper mould as seen from the mould or wire side of the paper. The wire shapes that create the watermark were often sewn to opposite sides of the mould, making mirror images of each other, as is the case with the standard *Sidereus Nuncius* stock (Figs. 2a–f). The standard stock, as discussed in *Galileo's O*, carries two watermarks, the main LA mark and a Tp cornermark.[4] SN Graz is depicted here with two mR leaves and two mL leaves as an example of the twin Tp cornermarks in the regular stock of genuine *Sidereus Nuncius* copies (Figs. 2c–f). Arrows point out some of the more obvious wire irregularities that, in addition to the watermark, are faithfully reproduced in each sheet made on the same mould. The markings in the mL pages 5 and 13 are the same, as are those in the mR pages 11 and 15. Comparing wire patterns is helpful in cases where the watermarks or other features are misleading, as illustrated by a variant detail of the Tp cornermark in *SNML* page 10r (Fig. 3). The extra bend at the end of the T crossbar (see blue arrow, Fig. 3c) could be mistaken for an upward extension, which would make the watermark a variant. In truth, it is one of the many sheet formation irregularities caused by unevenly dispersed bits of pulp that can hinder the comparison of watermarks.

4 *Galileo's O*, 2011, Vol. I, pp. 131–134 and Vol. II, pp. 21–24.

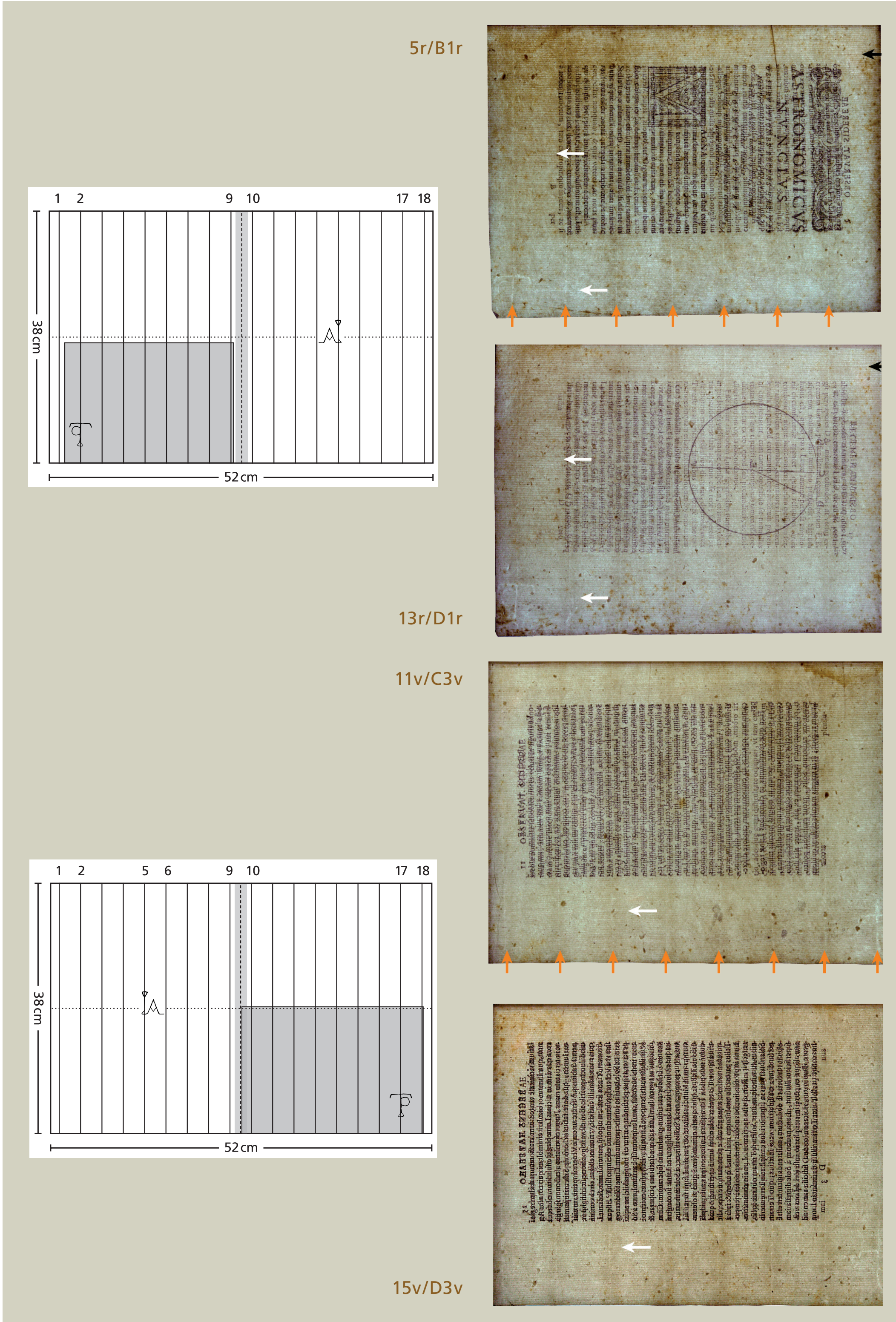


Fig. 2a–b: Diagram of the twin paper moulds for the standard stock of Sidereus Nuncius seen from the mould side, with the main watermark located either on the right side, mR (a) or on the left side, mL (b). The grey stripe indicates the crease that results from drying during production; the dashed line indicates the fold at the head of the book block, the dotted line indicates the gutter fold. The grey rectangles match the locations of SN Graz sheets in c–f.

a	c
	d
b	e
	f

Fig. 2c–f: Sheets made on twin moulds from the genuine SN Graz, seen from the mould side. Folios (c) and (d) are from the same mR mould, leaves (e) and (f) are from the same mL mould. Identical wire marks are indicated with arrow; leaf pagination, see Fig. 7.

a | b | c
d | e | f

Fig. 3: leaves with the Tp cornermark from the forged SNML seen in transmitted light, (mL). The similarities suggest that the sheets stem from the same mould. The watermark shape and adjoining laid lines (c, black arrow) as well as the spacing of the shadow areas (a, arrows on the right: orange arrows indicate coincidence of shadow with chain line, red arrows indicate shadow between chain lines) repeat in all of the Tp-marked leaves; (f) photographed out of plane. The blue arrow in (c) points to an extension of the cap of the "T" which is a sheet formation feature and not part of the watermark design. Grey arrows in (a) point to knots of unusual shape. White arrows in (d) and (f) point to water droplet patterns resulting from forgery (see similar but more obvious pattens in Fig. 6a, c, d).

The watermarks in the *SNML* paper were formed in the sheet during their manufacture, that is, not scratched or cut into the paper. This was confirmed by examining watermarked areas on the wire side of the paper under the microscope (Fig. 4). For comparison, page 2v of *SNML* (Figs. 4a–b) and 7r of SN Graz (Figs. 4c–d) are shown side by side. Both watermarks feature a triangle on top of the L in the LA main mark, the outline of which can be discerned in raking light (Figs. 4a and c). At higher magnification, one can see that fibres crossing the shallow recess of the watermark are undisturbed in both *SNML* and the Graz copy (Figs. 4b and d). Although the *SNML* paper surface is more "fluffy" than the gelatin-sized Graz paper, a point discussed below. The recess in the paper formed by the watermark wire seems to be genuine in the *SNML*.

In both *SNML* and the forged Padua *Compasso*, the forger failed to make twin papers. Each stock has only one mould. This can be seen in the comparison of genuine and forged sheets in transmitted light (Figs. 2 and 3). Four genuine SN Graz leaves with the "Tp"

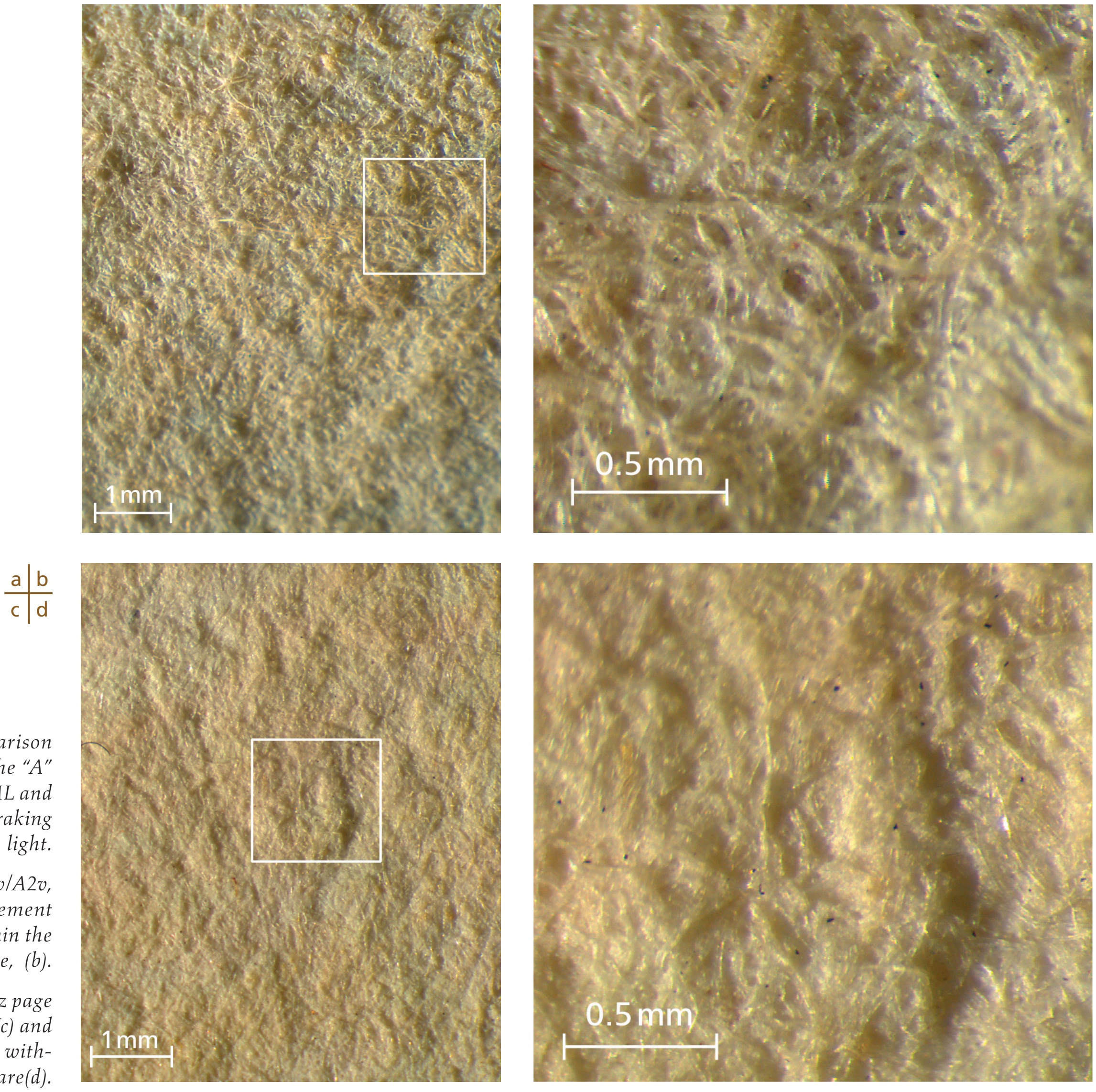


Fig. 4a–d: Comparison of the triangle on the "A" watermarks in SNML and SN Graz, seen in raking light.

Fig. 4a–b: SNML 2v/A2v, detail (a) and enlargement of area within the square, (b).

Fig. 4c–d: SN Graz page 7r/B3r, detail (c) and enlargement of area within the square(d).

corner mark (Fig. 2), five forged *SNML* leaves with the "Tp" corner mark (Fig. 3b–f), three leaves of the genuine 1655 *Discorso al serenissimo don Cosimo II Gran Duca di Toscana intorno alle cose, che stanno sù l'acqua, ò che in quella si muouono* [5] which follows the *SNML* in the Sammelband (Fig. 5), and four bifolia of the forged Padua *Compasso* (Fig. 6) are shown. In each figure, arrows mark patterns that repeat in the companion images. It should be pointed out that the chain lines are spaced on average 38 mm apart in *SNML* vs. 30 mm in the Graz copy, and 49 mm in the Padua *Compasso* vs. 28 mm in the Darmstadt

5 Galileo Galilei, *Discorso al serenissimo don Cosimo II Gran Duca di Toscana intorno alle cose, che stanno sù l'acqua, ò che in quella si muouono, seconda editione,* Bologna: HH. del Dozza, 1655.

a | b | c

Fig. 5a–c: Transmitted light images of pages 2 (a), 4 (b) and 18 (c) from Galileo Galilei's Discorso, Bologna 1655. The orange arrows to the right of (a) mark the shadow lines coinciding with chain lines. The arrows in (b) and (c) mark formation irregularities resulting from water accidentally dripped on the freshly formed sheets.

Compasso. The forged copies were clearly made on different paper moulds than the genuine copies.

In our first study, we determined that the bifolia in *SNML* stemmed from separate sheets (Fig. 7), but we had not determined that the eight Tp corner-marked papers came from a single mould, which would have raised suspicion (Fig. 3). One bifolium was originally misidentified as reading mR. We now confirm that all of the Tp cornermarked bifolia conform exclusively to the mL twin of the genuine *Sidereus Nuncius* standard stock. The shape of the Tp watermark and some of the intersecting laid lines (Fig. 3c, black arrow) repeat in every sheet (Figs. 3a–f). Other more subtle wire irregularities also appear in multiple Tp bifolia, though irregular sheet formation may conceal some. The LA bifolia also conform to the mL twin of the SN standard stock. The LA paper cannot be read as easily as the Tp in transmitted light because it is thicker and its watermarks lie partly concealed in the center fold, but there are sufficient similarities between its laid and chain line shapes to suggest that the *SNML* LA stock also stems from a single mould.

As for the Padua *Compasso*, a "Three Mountain" corner mark appears on each bifolium (Fig. 6). The watermark is always in the same upside down orientation in the top corner of the second leaf in relation to the printing. It is worth repeating that when it comes to printing, the watermark orientation of the paper is of no importance. That the paper is in the same orientation throughout the entire *Compasso* defies probability. In the short time available for examination of the Padua forgery, all the bifolia documented were made on the same mould, as indicated by unmistakable wire features (Fig. 6a, black arrows). This is improbable for any historic handmade paper. Provenance suggests that these forgeries may come from the same workshop, so it stands to reason that the *Compasso* paper was forged in a similar manner as the *SNML* paper. Both papers share crucial characteristics, though it appears that the *SNML* paper is a technically more advanced forgery.

The conclusion for *SNML* is that the forgers knew that each gathering had to contain both Tp corner-marked and LA center-marked sheets, but did not know about twin moulds

verso of title page with recto of facing page

11v/12r

15v/16r

33v/34r

a
b
c
d

Fig. 6a–d: Transmitted light images of bifolia from the forged Padua Compasso, verso of title page with recto of facing page. Despite some variances between the sheets, they were probably all made on the same mould. Red arrows in Fig. 3a point to shadows between chain lines, the orange arrow points to a shadow coinciding with a chain line, black arrows point to wire features repeating in every sheet. White arrows point to odd clusters of marks made by water droplets. The small shaded rectangles near the gutter are 2 cm scale markers.

and, for that reason, created two sets of papers to simulate what is one sheet in the genuine copies. When considering that the Tp and LA half-sheets for *SNML* were probably made on two separate moulds, the strange combination of thin and thick sheets found throughout *SNML* can be explained. All of the paper made on the Tp-watermarked mould is relatively thinner, and all the LA-watermarked paper is relatively thicker.[6] Noting this thin–thick combination in our earlier work, we did not realize that it followed the alternating watermarks. These sheets of differing thickness and density had to be alternated, not to average out the thickness and structural characteristics of the book as we postulated, but to arrive at the correct watermark sequence. Each quire requires one Tp and one LA watermark, which the forger could only have discerned upon close inspection of a genuine SN exemplar, since this information has not been published. The question remains: Why did the forgers fail to produce papers of similar thickness to combine them in one volume? It is possible that, in addition to their ignorance of twin moulds, the forgers did not even know that they were replicating full sheets of paper with two watermarks, rather than two different papers. If this was the case, they may have also thought that combining papers of different quality would add another muddling factor that would distract the viewer from the forgery.

PAPER STRUCTURE AND SHEET FORMATION: SHADOWS, KNOTS AND DROPLETS

Further comparison of *SNML* and Padua *Compasso* papers in transmitted light makes it clear that the mould construction of the forged papers does not properly replicate the antique-laid pattern of the genuine papers of the SN Graz and the *Discorso* (Figs. 2 and 5). These genuine papers have shadows surrounding the more translucent chain line. The chain line marks the location where the laid wires are stitched directly to the paper mould's wooden support ribs. This causes the extra pulp deposit during sheet formation and the characteristic shadow areas of antique-laid paper. In the case of both the *SNML* and Padua *Compasso*, the shadows appear at wider intervals than the chain lines, approximately matching up only every fifth chain line. In Figures 2, 3, 5 and 6, the red and orange arrows point out the locations of the shadows in the paper, the orange ones indicating where the shadow and chain lines overlap. In the forged papers (Figs. 3 and 6), these shadows match up only periodically. This departure from the normal pattern is not uncommon in historic papers, however, and can occur due to damage or repair of a paper mould. A wire surface loosened from the mould may cause the shadows to appear to one side of the chain lines, but this is likely to occur only locally in a sheet. In some rare cases, the shadows and chains do not align or they correspond only occasionally throughout the sheet. Paper used by Leonardo da Vinci that was apparently produced in Milan before 1500 shows shadows that appear between alternating chain lines.[7] This can be the result of the repair or reuse of mould components – an old mould wire being attached to a different old wooden support. To make the *SNML* and *Compasso* papers, the forgers likely had to alter existing moulds by at least

6 *Galileo's O*, 2011, Vol. I p. 135.

7 Jenny Bescoby and Judith Rayner, Supports and Preparations, in: Janet Ambers, Catherine Higgitt and David Saunders, eds. *Italian Renaissance Drawings. Technical Exmaination and Analysis*, London: The British Museum, 2010, p. 30. Fig. 4.8.

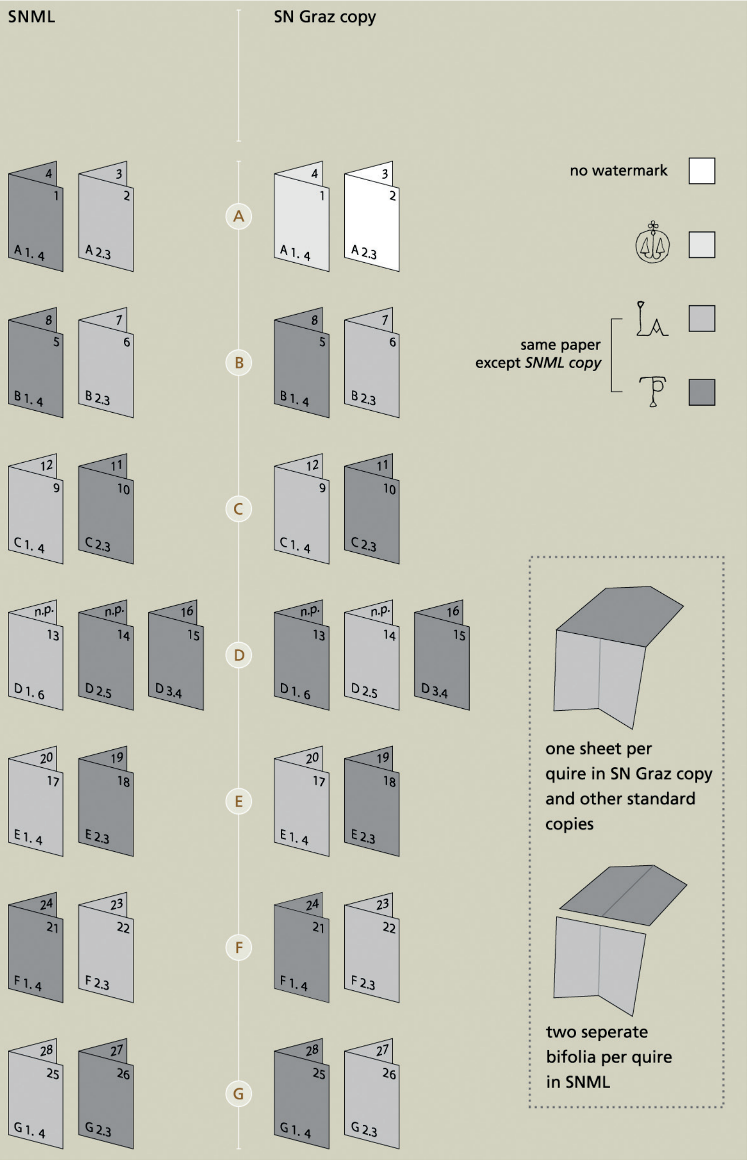


Fig. 7: Diagram of the quires and watermarks of the SNML and Graz copies. The SNML quires were made from two different half-sheets, while the Graz quires were made from a single, full sheet.

adding the watermarks, and perhaps even attaching a new wire surface to a wooden mould. It would have required some ingenuity and possibly the assistance of a learned tradesman to outfit the moulds necessary to produce the imitation papers with appropriate watermarks. This type of deceitful reuse of old mould components or old and new components seems the most likely explanation for the unusual shadow patterns observed in the *SNML* and Padua *Compasso* papers, and explains the convincingly "historical" appearance of both papers in transmitted light.

Before setting aside sheet formation issues, the fibre knots and water droplet patterns in the forged papers must be pointed out. In our first investigation, the preponderance of these features seemed consistent with a lower quality paper sold as seconds and supported our attribution of the *SNML* as a proof copy. During the recent examinations, the shape and

a
b|c

Fig. 8a–c: Forged SNML, pages 15v/D3v and 16r/D4r (a) (arrows point to brown-coloured fibre material in the paper); rectangle marks detail view showing paper fragment (b); paper fibre bundles and knots in the genuine SN Graz paper (c); (b) and (c) seen in transmitted light.

number of the fibre knots in the paper drew our suspicion. In the transmitted light images the fibre knots are visible as dark rounded spots in the paper. In authentic historical handmade paper, undispersed fibre knots result from clumps of pulp that dried on the stamper trough during pulp production, and were beaten into the next batch of pulp (Figs. 2 and 8c). In comparison with the SN Graz, the knots in *SNML* are more varying in dimension than those in the regular paper stock (grey arrows in Fig. 3a and Fig. 8a). One may also object to the shape of the knots as being too large and too oval to match the typical fibre knots seen in historic and stamper-beaten pulp. One example looks like a fragment of a paper sheet rather than clumped paper fibres (Fig. 8b). While old paper was often repulped to supplement supplies of worn rags, intact fragments of paper are not often seen in seventeenth-century paper.

Another suspicious characteristic is that some of these knots and fragments are distinctly browner than the rest of the paper. Where they are not completely covered by fibres, one can see that they contrast with the white paper (Fig. 9a). Where they are covered by

a | b

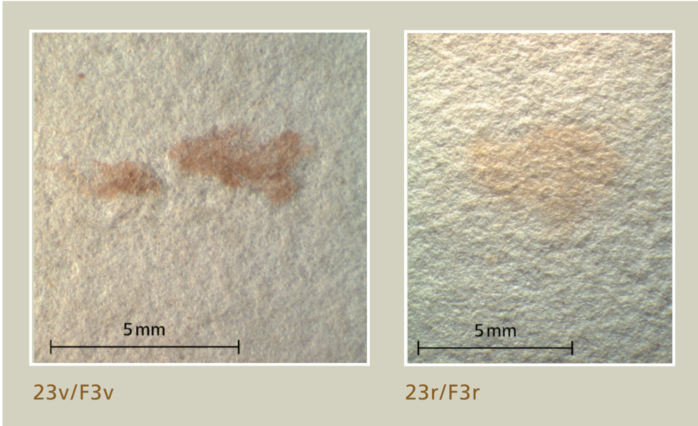


Fig. 9a–b: Details of darker paper fragments in the forged SNML. Page 23v/F3v shows the colour contrast between the fragment and the paper (a) and page 23r/F3r shows the same area on the other side of the sheet, where a faint darker area marks the location of the fragments covered with pulp (b).

white pulp, they are still darker than the rest of the paper (Fig. 9b). The presence of the dark pulp bits is highly unusual considering that quality sorting of the raw materials was key in papermaking. While brown papers intended for wrapping included all manner of source materials, such as coloured cloth, tarred hempen rope and used sails, a white paper would rarely have been tainted with brown stuff in such an ill-dispersed manner.

The genuine SN papers show only a few individual blue textile fibres as well as small brownish shives interspersed with the white pulp. Even high-quality white handmade paper of this era had faint brown flecks in its matrix. Referred to as "process dirt" or "shive", one source of this material is the linen cloth itself. Linen is made from flax fibres, which have an outer sheath that was not always completely removed in cloth production. When the cloth had been worn to rags and was used in papermaking, bits of remaining sheath would finally be separated from the fibres in the stamping trough. In the *SNML*, made from pure cotton linters with no flecks or process dirt, the addition of the darker fibre material was

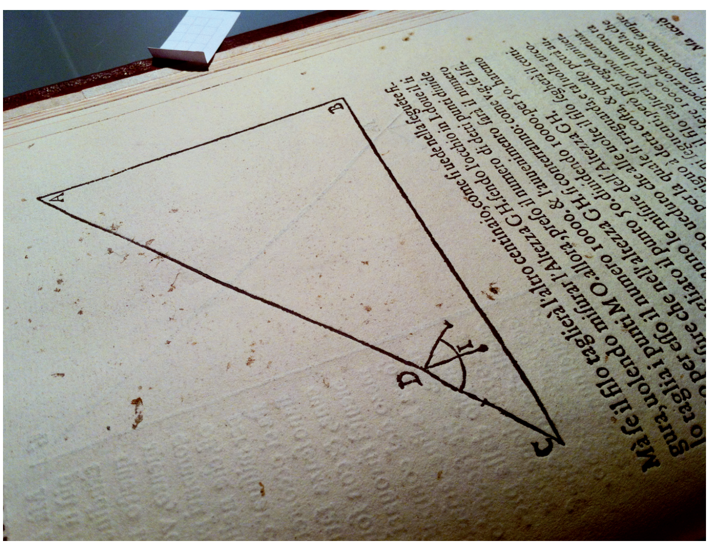


Fig. 10: Detail of the brown fibre bits and flecks adhered to the surface of the forged Padua Compasso.

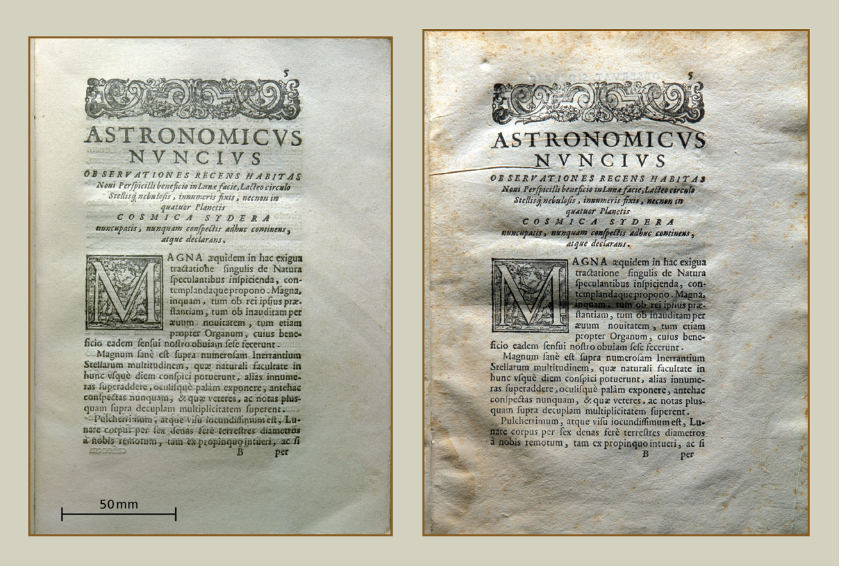
probably meant to simulate the shive. While visually similar to the knots and lumps found in stamper-beaten pulp, upon close inspection, the addition of these darker fibres and paper fragments is inconsistent with seventeenth-century white papermaking practice. The inclusion of brown fibres was a conscious endeavor to make the paper look more convincingly old, which becomes more evident in the *Compasso* where brown fibre bits are adhered across the paper surface in what appears to have been the earlier, and evidently cruder, attempt at paper forgery (Fig. 10).

Another unintentional mark of authentic historical handmade papers, deceitfully used in the *SNML* and Padua *Compasso*, is the so-called vatman or papermaker's tear. When water droplets fall on the still-wet fibre mat during paper production, the drops cause a local displacement of fibres, resulting in a thin spot in the paper that can be seen in transmitted light. Historical papers were not always made with the kind of perfection that is invested in most contemporary handmade paper, so droplet-tears as seen, for example, in the genuine *Discorso*, are not unusual (Fig. 5b–c, white arrows). Its loosely grouped tears look as if they were caused by a spray of random droplets, and the zigzag line (Fig. 5b) by runnels of water streaming from the mould deckle onto the wet fibre mass. The Padua *Compasso* features several large roundish clusters of densely packed water drop marks (Figs. 6a, c, d, white arrows). These unusual marks occur in conspicuous repetition and almost decorative distribution on the *Compasso* leaves, making the ones seen in the *SNML* (Fig. 3d and f, white arrows) look more suspicious than they did originally. While not a sign of forgery on their own, the clusters of marks in the forged papers are, in their concentration, unusual. Just as in the case of the deeply embossed printing, once we know the fraud, we cannot help but argue that in the end, the forgers went overboard in faking some of these historic marks, which is noticeable in both the shape of the fibre knots and the clustering of the vatman's tears.

PAPER PLANARITY AND SIZING

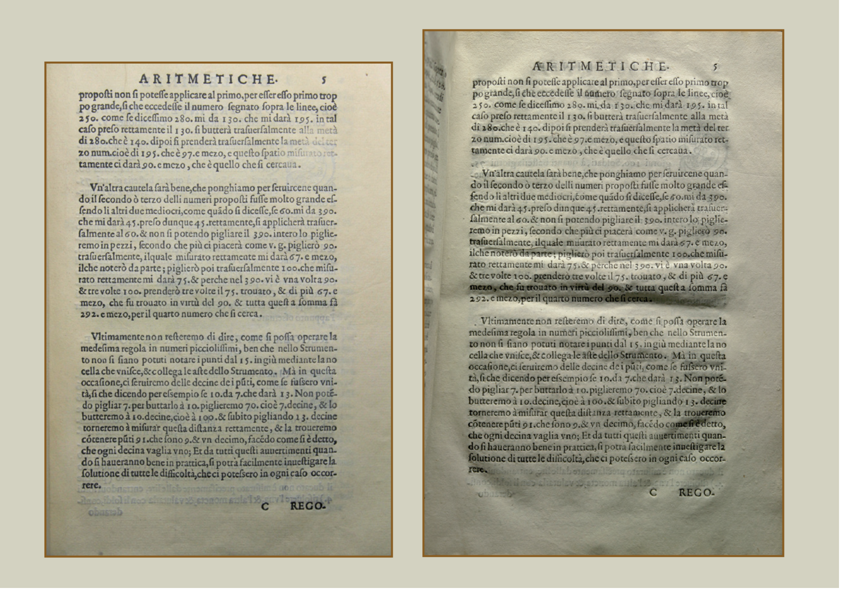
As can be seen in the raking light comparisons of page 5r of the *SNML* and SN Graz (Fig. 11), and the Padua and Darmstadt *Compassos* (Fig. 12), the forged papers lack the normal undulations seen in the real papers. This is a result of printing the paper while dry, as is the modern technique with letterpress printing (from both moveable type and polymer plates). As discussed above, possible evidence of the photographic process used in producing polymer plates appears on several pages (see chapter II and Fig. 27). The genuine copies were letterpress printed on dampened paper according to the techniques of historic practice. Dampening makes the paper softer to better accept the type impression and causes the paper to expand in size. The pressure of printing selectively compresses the moist paper where the text occurs, leaving the margins uncompressed. As the paper dries and shrinks after printing, the layer of ink in the deep impression of the type inhibits the shrinkage of the paper in the center, but not in the unprinted margins. This uneven shrinkage results in the undulations seen in the genuine paper throughout each text block. In the case of *SNML*, a slight undulation only manifests itself towards the end of the book where the pages begin to conform to the neighboring genuine pages of the *Discorso*.[8]

8 *Galileo's O*, 2011, Vol. I, p. 84.



a | b

Fig. 11a–b: Raking light images of page 5r / B1r of the forged SNML (a) and the genuine SN Graz (b). The forged paper lacks the characteristic undulations seen in the genuine paper.



a | b

Fig. 12a–b: Raking light images of page 5r of the forged Padua Compasso (a) and the genuine Darmstadt Compasso (b). The forged paper lacks the characteristic undulations seen in the genuine paper.

Both forged papers were deeply impressed from the impact of what we now know to have been a modern relief plate (Figs. 13 and 14). In genuine exemplars, the paper was sized before printing and then was dampened to receive the printing impression. The paper around the letters lost some of its deep relief during the preparatory steps for binding. It was traditional to beat the text block with a heavy hammer to compact the pages (see also chapter IV). This would have diminished the embossment of the printed text, and sometimes results in wrinkles around the letters (Figs. 13b and 14b). In our first campaign, we associated the deep embossment of the *SNML* with the fact that, unlike the other copies

a | b

Fig. 13a–b: Details of the title pages of the SNML (a) and the SN Graz (b), seen in raking light. In the genuine paper, the printed impression has been somewhat flattened by beating the text block before sewing in preparation for binding.

studied, its paper carries much less, if any, gelatin sizing. Re-inspecting the sheets under near ultraviolet radiation confirmed our earlier findings (Fig. 15). The papers appear purplish-blue overall. In other words, they do not fluoresce strongly, indicating the absence of

a | b

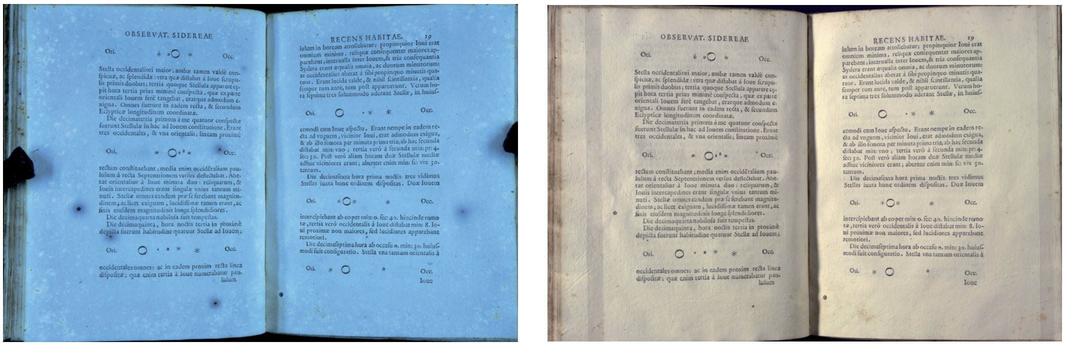
Fig. 14a–b: Details of the title pages of the forged Padua (a) and genuine Darmstadt Compassos (b), seen in raking light (explanation as above). A loosened paper fragment in (a) reveals a lighter coloured paper beneath (see chapter V).

gelatin sizing comparable to the other SN copies examined. The SN Graz paper shows a more intense, overall fluorescence that is typical of naturally aged historical papers (Fig. 16). It also shows something else that is commonly found in aged book paper: spots in the margins that are brighter under UVA, but are not (yet) visible as stains under normal light. These are related to environmental factors – exposure to moisture, fluctuating temperature and humidity levels, and air-borne pollutants – that affect the exposed perimeter of the paper in a book more than its center. That the *SNML* paper lacks such aged-margin patterns was not originally considered significant, but now supports the argument that the paper is modern.

Under ultraviolet examination, a few leaves of *SNML* show a faint, darker pattern not previously observed that results from a diminished reflectance, i.e. greater absorption of UVA. The odd pattern has several distinctive features. The affected leaves show a slightly blurry, darker blue vertical stripe (Fig. 15a–c, black arrows). In several instances, there are also perpendicular lines, best seen in the gutter area (Fig. 15b). The stripe always shows on both sides of the leaf and is not noticeable in visible light (Figs. 15d and e). In Figure 17 bifolium 5v–8r is digitally assembled to show the half-sheet produced for the forgery. Under

Fig. 15a–e: Selected pages of the SNML under UVA-induced visible fluorescence (a–c) and under normal light (d–e). The black arrows (a–c) indicate a previously unnoticed pattern of darker lines only visible under ultraviolet examination. The white arrows (a–c) point out fingerprints.

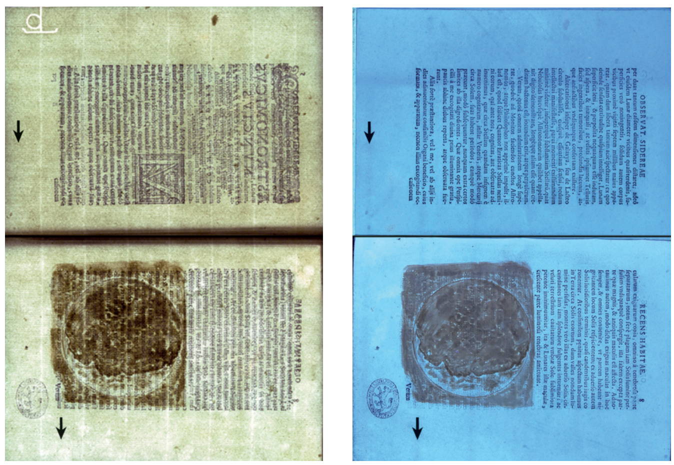
ultraviolet examination (Fig. 17b) it too has a wide, dark blurry line close to the left margin of the paper; thinner, dark lines run perpendicularly across both pages. This is most visible at the bottom of the pages (black arrow) and in the unprinted gutter area. These lines run parallel to, but do not fully correspond to either the chain or the shadow lines (Fig. 17a). Finally, UVA also reveals fingerprints that fluoresce brightly in the lower right margin of page 5r and at the bottom of page 9v (Figs. 15a and c, white arrows). Both the stripe pattern and the fingerprints, visible only under UVA examination, must be connected to the forgery production. It is most likely that these patterns relate to the manipulation of the paper after the sheets were formed, perhaps during the application of a surface coating as discussed further below. In authentic historical paper, any of these marks could have been accepted as indications of possible past restoration or an unexplained aging effect. While odd, they might not spark suspicion. In light of the fact that we now know the paper to be of modern manu-



a | b

Fig. 16a–b: Pages 18v and 19r of the SN Graz under UVA-induced visible fluorescence (a) and under normal light (b).

facture, they are doubly perplexing. By drawing attention to these unexplained features, we hope that these and other details of the paper manufacture will eventually come to light to aid in our understanding of the forgery production.



a | b

Fig. 17a–b: Bifolium 5v–8r of SNML shown in transmitted light (a) and with UVA-induced visible fluorescence (b). Black arrows in (a) indicate horizontal line pattern showing low fluorescence that do not correspond to chain lines in (b).

The forged Padua *Compasso* paper shows a more distinctive manipulation that is indicative of surface coating. When we examined the Padua paper with a small handheld UVA radiation source, we found that the paper showed as little UVA-induced fluorescence as the *SNML*, which confirms the lack of naturally aged gelatin sizing in both papers. A few other features of the *Compasso* paper, however, bear mentioning. First, the paper feels somewhat stiffer than *SNML*, and too stiff for an unsized paper. Second, its surface feels a bit gritty, and third, it shows a slight sparkle in reflected raking light. The grittiness and sparkle most likely relate to a surface coating applied to replicate the haptic quality, the "feel" of a historic paper stock. On page Q2v there are a few translucent adhesive blobs that are water-soluble. The newly made paper may not have proven strong and crisp enough to match the genuine stock, so the forger stiffened it without being careful or knowledgeable enough to replicate historic gelatin sizing methods. A number of agents, all readily available in craft

and art stores or from conservation suppliers, could have been prepared to be brushed or sprayed on the paper or made into an immersion bath.[9] A concoction of such agents, even including gelatin as an ingredient, is possible. Applied in the appropriate concentration, such "sizing" stiffens paper and imparts some slight resistance to water absorption, as is more evident in the Padua *Compasso*. It should be noted that the paper from the forged Lima *Life of Galileo* is also gritty and sparkles much like the Padua *Compasso*. Applying the insight of these acknowledged forgeries to the *SNML* case, it is therefore conceivable that the *SNML* paper received a surface treatment, but one that was more subtle and therefore did not cause grittiness or sparkle as a give-away. Wet paper is heavy, fragile and difficult to handle. If a treatment was applied, the paper may have required a physical support during the application and drying. The stripes may result from an uneven distribution of the coating where the paper was in contact with the support structure.[10] Assuming a connection between the production of these three forgeries, the differences in the papers of the Lima letter, the Padua *Compasso* and *SNML* suggest the methodical refinement of systematic forgery production.

CREATING AN AGED LOOK

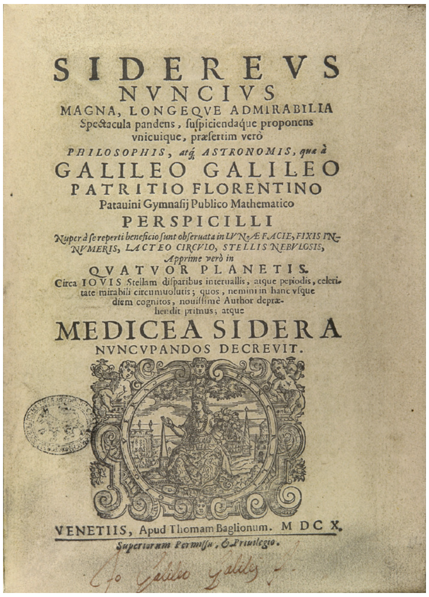
Once we determined that the printing was false, everything else began to look suspicious as well. Even before fibre analysis confirmed the modern fabrication, the patterns of soiling and the brownish paper colour became suspect. Why does the soiling extend over the whole signature and then rise up to the right on the title page (Fig. 18a)? Why is there a perfectly horizontal line of clean paper beyond the soiling on the edge of page 11r (Fig. 19)? Suddenly, the signs of use that had lent credibility to the age of the paper and thus the printed text during our first examination were sure signs of intent to deceive.

Several types of soiling appear to have been rubbed on the paper. Some soiling replicates the grimy marks that accumulate on page corners over time with even careful handling. Other soiling replicates the dirt, soot and dust that would settle in a book during decades or centuries of upright storage on a bookshelf. Further, there is evidence that colour was applied to the paper, overall and locally, to suggest the discolouration that comes with age. The forgers had a good grasp of how a naturally aged and used book should look, but they failed to understand the different sources for the discolourations found in old books, and the different processes of their deposition, which were the clues that proved these marks false.

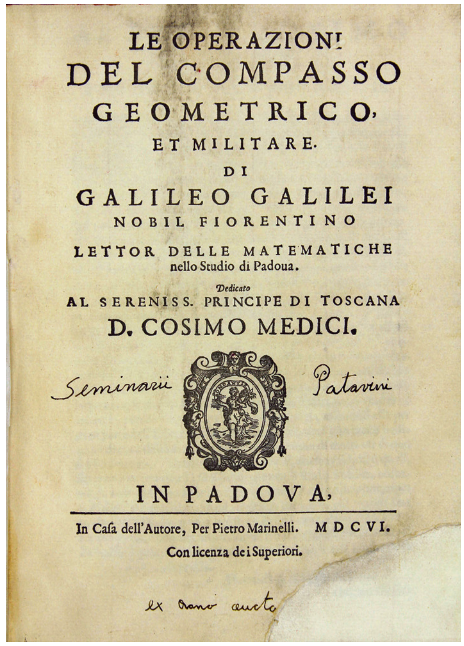
The marks that imitate historic handling are most conspicuous and therefore a good starting point for discussion. The forgers did quite well in creating grimy page corners.

9 They include carrageen moss, an algae used for paper marbling; gum Arabic, a common ingredient in artists' drawing and painting materials; or a cellulose ether, commonly available as wallpaper adhesive and, in selected pure varieties, as a conservation adhesive and re-sizing agent.

10 The possible coating application did not make the *SNML* paper significantly water-resistant, as is seen by its ready absorption of the aqueous drawings ink and confirmed by our water droplet tests. Small beads of water were transferred to the paper surface from the tip of a 00 brush in locations chosen to be inconspicuous, in this case the lower gutter of selected sheets. The droplets were absorbed immediately (less than one second delay).



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS INNVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author depræhendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.



LE OPERAZIONI
DEL COMPASSO
GEOMETRICO,
ET MILITARE.
DI
GALILEO GALILEI
NOBIL FIORENTINO
LETTOR DELLE MATEMATICHE
nello Studio di Padoua.
Dedicato
AL SERENISS. PRINCIPE DI TOSCANA
D. COSIMO MEDICI.
Seminarii Patavini
IN PADOVA,
In Casa dell'Autore, Per Pietro Marinelli. M D C VI.
Con licenza de i Superiori.

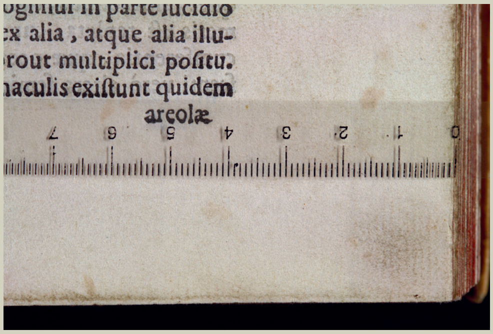
a | b

Fig. 18a: Title page of SNML showing the curious pattern of soiling.

Fig. 18b: Title page of the forged Padua Compasso showing applied soiling.

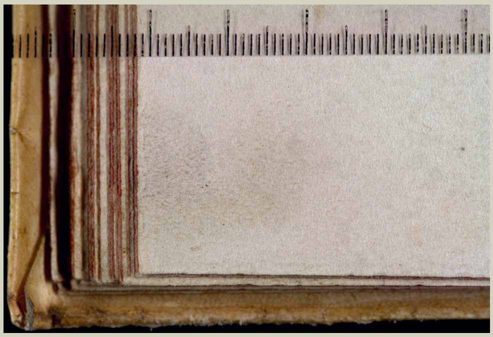
Beginning on the title page, there is visible surface soiling overall and more heavily at the lower right corner of many pages, as might be expected. However, close inspection reveals unnatural patterns within these marks. On the title page, the soiling covers the entire signature and then rises to the right before joining the corner soiling, leaving a clean area at the lower edge of the page (Fig. 18). This is a strange pattern. If the page had been handled repeatedly, enough to cause such strong soiling, this area could hardly have been avoided. Also, the dirt is most heavy over the signature, rather than at the corner, as if it had been stroked repeatedly, like the faces of medieval icons, worn away from touch. This pattern reveals an intentional application of dirt to the page. A similar though cruder pattern of soiling decorates the title page of the Padua *Compasso*; it was obviously made with the similar intention of creating a used look (Fig. 18b). Some other pages of *SNML* have strong soiling at the corners that does not extend to the edge of the paper (Fig. 20).[11] In fact, the clean area is defined by a straight line of dirt. It is hard to imagine how this would occur during normal use. In authentically old books, the oily grime from the touch of fingers builds up only gradually over time as the pages are turned repeatedly. Any page would not be touched in the same spot every time, so the grimy area would usually be roundish, concentrated in the page corner, and with a soft transition towards the clean paper, a pattern that is not quite matched in *SNML*. Furthermore, it is rare to find marks from individual and excessively dirty fingers as seems to be the case on several pages (Fig. 21).[12]

11 For other examples, see *Galileo's O*, 2011, Vol. I, pp. 57–87.
12 For other examples, see *Galileo's O*, 2011, Vol. I, pp. 57–87.



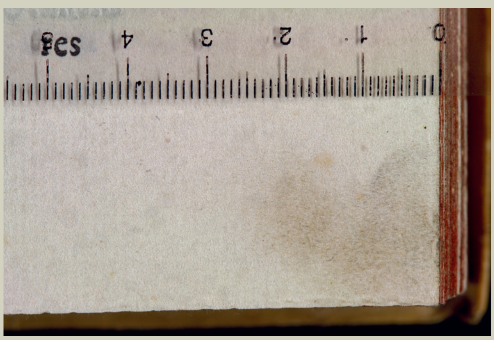
11r / C3r

Fig. 19: Detail of the lower right corner of page 11r / C3r of SNML showing the clean edge of the paper. Scale is marked in mm.



21v/F1v

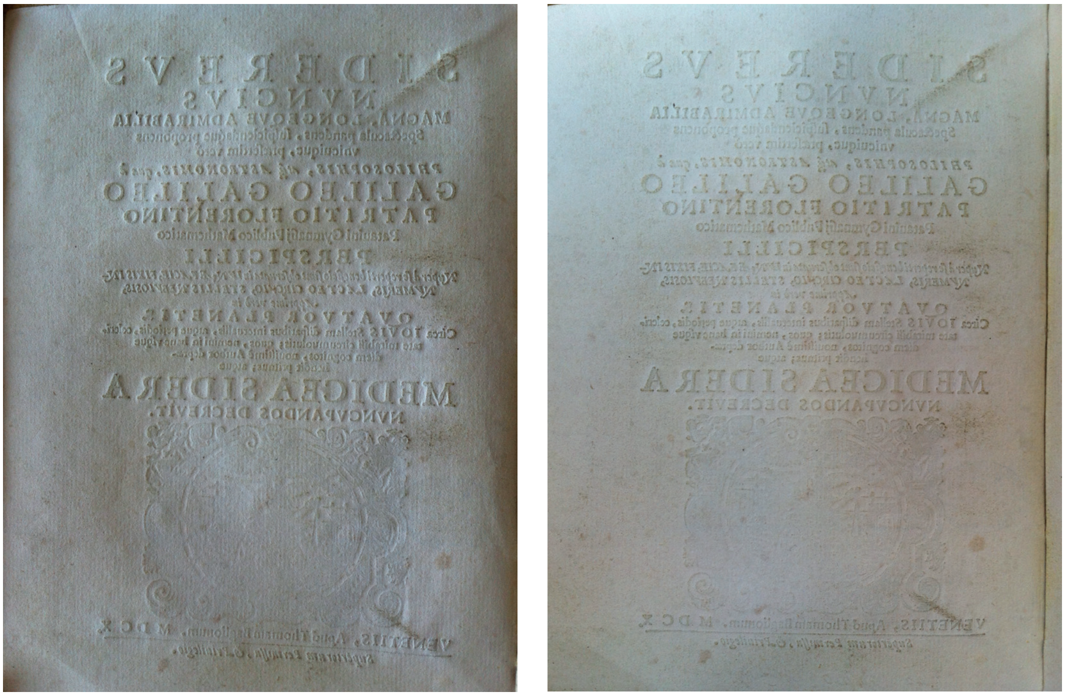
Fig. 20: Detail of the lower left corner of page 21v / F1v of SNML showing soiling that stops short of the edge of the page. Scale is in mm.



22r/F2r

Fig. 21: Detail of the lower right corner of page 22r / F2r of SNML showing a distinct fingerprint. Scale is in mm.

Soiling also appears in areas of the pages that one would not expect to be soiled. This is particularly evident where the cores of the endbands are laced through the cover of the book. The cores visibly protrude under the paper of the paste down and indent the facing title page, dramatically seen on its verso in raking light (Fig. 22a). One might expect to find some dirt on the raised area of the protrusions, however here we find that the ridges formed by the lacing are dirtier than anything else on the page (Fig. 22b), even on the underside of the protrusion. Dust, soot, and coal dust particularly, are commonly found deposited on the top edge of a closed book and inside the book wherever there are small gaps between the pages. These fine air-borne particles deposit over the entire accessible paper surfaces regardless of topography, but most heavily at the entry point. For instance, the thickness of a folded plate within a book will leave a slight gap in the top edge and along the gutter



a | b

Fig. 22a–b: Page 1v / A1v of SNML seen in raking light (a) and in normal light (b).

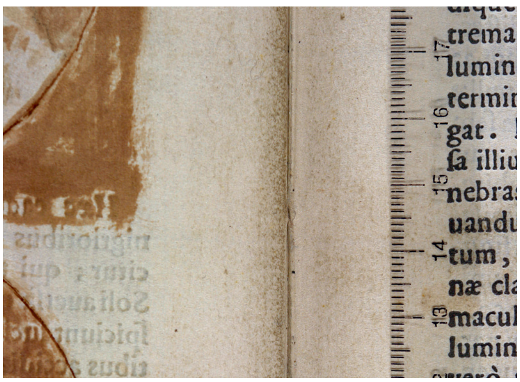


Fig. 23: Detail of gutter between pages 10v and 11r of SNML showing unusual pattern of dirt accumulation. Scale is in mm.

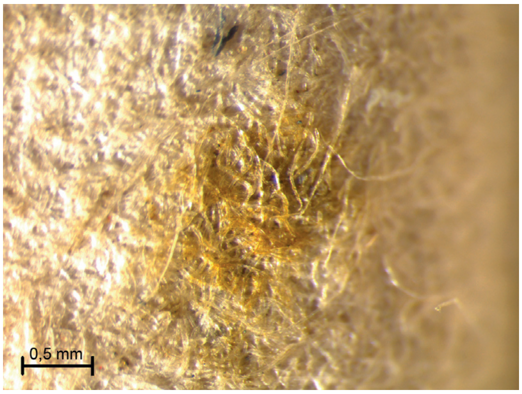
Fig. 24: Closer detail of Fig. 23.

where soiling is often found. Protruding binding elements such as the endband lacing can also create a gap between the cover and the book pages. However, if *SNML* had naturally accumulated dust, it would be accumulated on the top of the protruding lacing, close to the top of the text block, its presumed point of entry. It wouldn't be under the protrusions. It must be stressed that dirt from handling does accumulate predominantly on the high points of a page, but air-borne soot and dust travels into a book and deposits evenly on high and low points of the paper alike, creating a more even appearance. These dirty marks could only have been applied by hand.

Another place that dirt naturally accumulates in books is the gutter. It is not unusual to find dust, fibres from clothing, food crumbs and all manner of loose dirt in the gutters of books. Generally this dirt can be brushed away and does not leave a mark. We did find some of this in the *SNML*, but what caught our attention on this viewing were some extremely

grimy gutters, for example between pages 10v and 11r (Figs. 23–24). Instead of an accumulation of dirt in the lowest point of the gutter, the areas adjacent to the gutter are quite soiled, as if a dirty finger was rubbed over the gutter area without quite reaching its depth. When the sewing thread was moved aside, a perfectly clean line of paper was visible beneath it (see chapter IV, Fig. 3).

The forgers' knowledge of which areas of a book should be dirty was originally convincing. As with the other aspects of this sophisticated forgery, our belief in the authenticity of the book convinced us that what we saw was natural. Awakened, as our eyes were in the latest examinations, we saw what was unnoticed before. The surface soiling throughout is the result of a manual manipulation of the page surfaces.



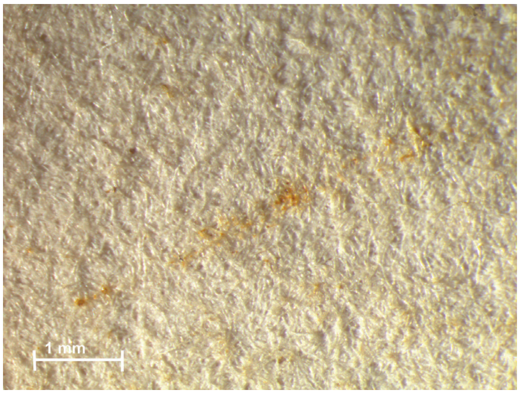


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Fig. 25a–b: SNML, photomicrographs of undissolved dye particles on page 8v/B1v at 32x magnification (a) and between pages 18v/E2v and 19r/E3r at 50x magnification (b).

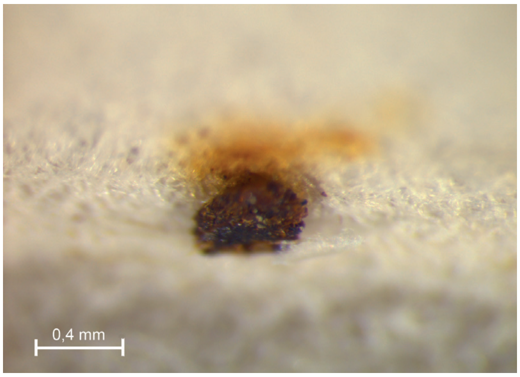

Fig. 26: SNML, detail of yellow-orange colourant found on right page of Pleiades spread (unpaginated, D6r).

Now we turn to patterns of natural discolouration of paper upon aging. Paper yellows and changes colour over time depending on the materials of its manufacture, how it was used, and its storage conditions. In general, paper yellows for several key reasons. Gelatin sizing darkens with age; metal ions in the process water tend to cause overall browning; metal particles from the papermaking equipment can leave small specks that catalyze paper degradation in localized spots called foxing.[13] Exposure to light, heat, moisture and pollutants also darkens paper. In books this is seen especially at the page edges where exposure

13 Soyen Choi: Foxing on paper: a literature review, in: *Journal of the American Institute for Conservation* 46 (2007): pp. 137–152.

is greatest. The papers in the *SNML* and Padua *Compasso* forgeries are of a similar muted yellowish-brown colour – darker than the standard stock of *Sidereus Nuncius* papers. This colour was probably applied overall as a liquid and locally with dry media. To simulate the yellowing of age, it seems the paper was tinted with a liquid colourant, probably a dye. We found very small specks of yellow-orange colourant deposited on some pages. Rather than discrete pigment particles, the specks look like undissolved dye concentrated in spots, as on pages 8v and the gutter between pages 18r and 19v (Fig. 25). Here the partial dissolution of the concentrated particle results in an orange-yellow stain, demonstrating its colouring action.

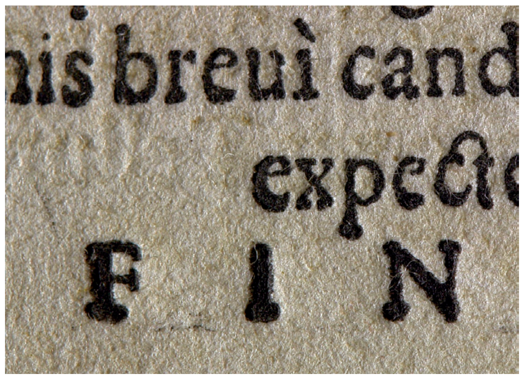

Fig. 27: SNML, detail of page 28v/G4v showing loose, twisted cotton fibres on the roughened paper surface, and faint imprint of the polymer printing plate edge around the letters of „FINIS".

The same, or a similarly coloured, material was also applied to the pages locally, perhaps to replicate stains or perhaps accidentally. On the page spread depicting the Pleiades (not paginated), there is a yellow-orange line of colourant on the right page (Fig. 26). Stripes and spots of colourant were also observed on pages 17r, 17v, 18r and 18v, as discussed above.

In addition, the paper surface seems to have been purposely roughened overall, most noticeably in the blank areas around the text. Under the microscope we can see fibres loosened from the paper substrate and standing up from its surface (Fig. 27). These are not isolated spots that could be the accidental result of local abrasion; they are visible in wide areas across the paper margins and especially on the fore edges of individual pages, especially on the title page, page 14r and page 17r. The long double crease in leaf 5 of *SNML* (see Fig. 11a) may be the result of physically distressing the paper surface so that it would look aged. The overall roughening probably resulted at least in part from the physical application of surface soiling to the fluffy, unsized cotton paper. It may have been intended to add "wear" to the pages, or it may have been an unintended consequence of the paper manipulations discussed above.